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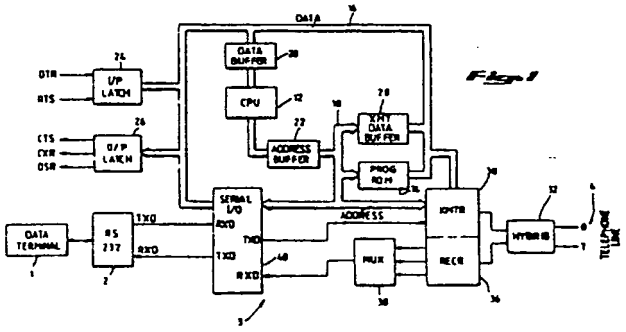
(54) High speed modem.

(57) A modem is disclosed having a data transmission protocol involving lower-speed, full-duplex operation during the connect sequence with a remote modem and an automatic switch to higher-speed, half-duplex operation for data transfer. Further, the modem data transmission involves transparently changing between lower-speed, interactive operation and higher-speed operation based upon data transmission demands. The operation is controlled by a processor monitoring the contents of a transmit data buffer and providing a mode control command to the modem transmitter. The modem also adapts its speed to the quality of the telephone line by fallback or fallforward to a different speed based upon predetermined data frame retransmission criteria.



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HIGH SPEED MODEM

The present invention relates to apparatus for communicating data over a telephone line; and more particularly, it relates to apparatus employing a communication protocol involving both higher-speed, half-duplex and lower-speed, full-duplex operation based upon data flow demands.

Communication of data over a telephone line is accomplished by devices that transform a typical two-level digital computer signal into a form suitable for transmission over the telephone network. For example, the two-level signal is converted into a two-frequency sequence of signals. The conversion involves modulation at the transmitting end of the line and demodulation at the receiving end of the line. Devices providing these modulation/demodulation functions are referred to by the acronym "modem".

A modem is typically inserted between a data terminal and the telephone line. A modem is, therefore, a two-port device having a first interface to the data terminal and a second interface to the telephone line. Control of the modulator/demodulator functions can be by a control circuit on either side of the interface to the data terminal. Control codes for modem operation may be provided from the data terminal to a control circuit via the interface. Typically, the control codes will be embedded in the serial data stream from the data terminal. A control circuit coupled to the interface receives the control commands and acts based upon them to generate control signals for the modulation/demodulation functions. Alternatively, the data terminal may generate the control signals for the modulation/demodulation functions.

In order to send digital data between transmitting and receiving locations, a carrier signal is modulated based upon the data values to develop a transmit signal. Telephone lines have a limited bandwidth for signal transmission. The term "bandwidth" refers to the range of transmit signal frequencies which can be passed without significant attenuation. The range of frequencies of a transmit signal, and thus the amount of bandwidth of the telephone line occupied, is dependent upon the baud rate at which data is being sent. As the speed of data transmission increases, the amount of available bandwidth occupied also increases.

Typically, data transmission rates over telephone lines will be 300, 1200, 2400, 4800, 7200 or 9600 bits per second ("bps"). At the fastest speed of 9600 bps, essentially the entire bandwidth is occupied by the transmit signal frequencies. For two way communication between data terminals, half-duplex operation is typically used. This involves each modem alternately placing its transmit signal on the line. At the slower speeds, less of the total available bandwidth is occupied. The total available bandwidth can be separated into upper and lower frequency bandwidths. By selecting separate carrier frequencies, the transmit signals will occupy separate bandwidths. This allows both transmit signals to be placed on the line at the same time for two way communication. Such communication is referred to as full-duplex operation.

The required communication speed is generally dictated by the data transmission demands of a particular application. For the transfer of files of data between data terminals, high speed data transmission is demanded to reduce the required time the telephone line is in use. For interactive communication between data terminals, full-duplex operation is desired. In some circumstances, there is the desire to both send data files and to have interactive communication. In such circumstances, the call connection often must be terminated and reestablished in order to change between operation protocols. Alternatively, time-consuming command exchanges must be made to reverse the communication roles or "turn the line around."

There is a need for higher-speed data transmission over dial-up telephone lines while retaining a full-duplex appearance at the data terminal interface. Further, there is a desire for error control along with maximum thruput and minimum echo character delay. However, economic considerations also are of concern.

Full-duplex, 9600 bps communication can be achieved using echo cancellation per V.32 standard. This solution is expensive because of the complex apparatus involved. Other approaches include fast poll, half-duplex operation using a single channel multiplexer in accordance with the V.29 standard. This operation involves line turn-around to get a minimum echo delay but does not achieve maximum thruput with error control. Alternatively, slow poll, half-duplex operation can be used but minimum echo character delay is not achieved.

The present invention economically provides the desired higher-speed data transmission and satisfies the full-duplex appearance, error control and minimum echo character delay requirements.

In one aspect of the present invention, data transmission automatically changes from lower-speed, full-duplex operation to higher-speed, half-duplex operation based upon data transmission demands. The transmission mode transparently changes from a lower-speed, interactive mode to a higher-speed data transmission mode as data transmission demands dictate. In accordance with this aspect of the present invention, during the

handshake sequence between calling and answering modems, operation is in the lower-speed, full-duplex mode. When a large amount of data is to be sent, as in a file transfer, transition is made to the higher-speed mode.

In accordance with the present invention, a transmit data buffer is monitored. The lower-speed, full-duplex transmission mode is maintained until the buffer contains a predetermined number of characters. Operation then switches to higher-speed transmission. The transmitter is selectively operable in either a lower-speed, full-duplex mode or a higher-speed, half-duplex mode.

In another aspect of the present invention, data communication automatically changes between lower-speed, full-duplex operation and higher-speed, half-duplex operation based upon data transmission demands during a communication. In accordance with this aspect, during interactive communication, operation is in the lower-speed, full-duplex mode. When a large amount of data is to be passed, operation is changed to the higher-speed, half-duplex mode.

In yet another aspect, the present invention provides for incremental changes in the speed of data transmission based upon determinations of data transmission error. In accordance with this aspect, data transmission speed is adapted to the quality of the telephone line as determined by the extent of data retransmissions. Frequent data retransmission directs a fallback in speed. As the number of errors is reduced, the data transmission can fallforward in speed.

A written description setting forth the best mode presently known for carrying out the present invention, and of the manner of implementing and using it, is provided by the following detailed description of an illustrative embodiment represented in the attached drawings herein:

FIG. 1 is a generalized block diagram of a modem in accordance with the present invention;

FIG. 2 is a functional diagram of the telephone line interface;

FIGS. 3 and 4 combined provide a functional diagram of the modem more generally diagrammed in FIG. 1;

FIG. 5 is a diagram illustrating the connect sequence for the modem of FIGS. 1-4;

FIG. 6 is a flow chart diagram of an operational sequence of the modem of FIGS. 1-4 involving lower-speed, full-duplex linking of the modem and subsequent higher-speed, half-duplex data transmission; and

FIG. 7 is a flow chart diagram of an operational sequence of the modem of FIGS. 1-4 involving data transmission that automatically changes between lower-speed, full-duplex and higher-speed operation based upon data transmission demands during a communication and the quality of the transmissions.

Referring to FIG. 1 of the drawings, there is presented a generalized functional block diagram of apparatus for implementing the present invention. The apparatus provides for communication of data and control commands over a telephone line to a remote site. The apparatus of FIG. 1 provides a data communication unit which generally includes a data terminal 1, an RS-232 interface 2 (port 1)and a modem 3 coupled by a hybrid circuit (port 2) to the ring (R) and tip (T) conductors of a telephone line 4. The RS-232 interface refers to a standard established by the Electronics Industries Association which defines the signal interface couplings between data terminal equipment and data communications equipment employing serial binary data interchange. As used herein, the term "data terminal" refers to any external device having an RS-232 interface for providing or receiving digital data. In particular, the data terminal may be a computer, including any of the so-called "personal computers." However, the data terminal may be a printer or an information display system. Further, a parallel interface may be used and such would be fully functionally eqivalent to the serial interface in the context of the present invention.

The general function of the modem 3 is, of course, to send and receive digital data. The modem accepts digital data from a data terminal and places a transmit data signal on a telephone line for communication to a remote modem coupled to a data terminal. The transmit data signal is an analog signal obtained through modulation of a carrier by a digital input. During data communication to a remote modem, the transmit data signal will contain data from the data terminal which has been encoded into the appropriate signal structure according to the applicable Bell Telephone or CCITT standards. It is to be understood that the modem also places signals on the telephone line that allow the answering modem to link with the originating modem. This involves communication of a number of parameters that allow the receiver to establish carrier detection, adjust automatic gain control circuits, establish timing synchronization, converge and adapt the equalizer to the initial line conditions, and synchronize the descrambler. Also, in the initial linking procedure, referred to in the art as the "handshake" sequence, tones will be placed on the telephone line.

In addition to accepting digital data from the data terminal for communication, i.e., TXD, and providing received digital data to the data terminal, i.e., RXD, there may be an exchange between the modem and the data terminal of various control signals such as data terminal ready (DTR), request

to send (RTS), data set ready (DSR), clear to send (CTS) and Carrier (CXR). The various exchanges between an originating modem and an answering modem in the handshake sequence and in linking are well known to those of skill in the modem art. Similarly, the various exchanges between a modem and the data terminal to which it is coupled including the above-mentioned DTR, RTS, DSR, CXR and CTS signals are also well-known to those of skill in the modem art.

In the modem shown in FIG. 1, a control circuit in the form of a processor is provided to direct the overall operation of the modem and execute a sequence of instructions to control the various elements of the modem. The processor includes a central processing unit (CPU) 12 and a program read only memory (ROM) 14. The program ROM 14 contains instructions for directing the various operations necessary to effect the overall operation of the modem. The CPU obtains instructions from the ROM 14 and interacts with the various modem elements over a data bus 16 and an address bus 18. CPU 12 is coupled to the data bus by a data bus buffer 20. Similarly, the CPU is coupled to the address bus by an address bus buffer 22. An input latch 24 is also coupled to the data bus and receives inputs to be obtained by the CPU during the course of its operation. Among the inputs are those of DTR and RTS received from the data terminal through the RS-232 interface. An output latch 26 couples to the data bus and permits the CPU to place output information to elements requiring command code inputs. Also, among the outputs from the CPU handled by the output latch 26 are the DSR, CXR and CTS outputs to the data terminal.

As will be appreciated, the control circuit functions of data control and modem control may be assumed by the data terminal. For example, the CPU in the data terminal may in accordance with appropriate software instructions provide some or all of the functions of data and modem control. Alternatively, a separate circuit, peripheral to both the data terminal and the modem, may be interconnected to provide the control circuit functions.

Further, while the data terminal 1 in the illustrative embodiment provides a local site data source, data for communication may be otherwise provided. Similarly, while communication may be to a remote modem coupled to a remote data terminal serving as a remote data source and receiver, other data receivers are contemplated. For example, the remote modem may be interfaced to a remote data receiver in the form of an information display system such as a printer or character generator for a display device. Moreover, a remote data receiver may include data transmission capability, for communication back to the local site.

The modem 3 in Fig. 1 further includes a transmit data buffer 28 receiving digital data from the data terminal for communication. The transmit data buffer may be physically located on either side of interface 2. Also, the buffer can be within the data terminal or in an interconnected peripheral. The data is routed through serial I/O device 40 onto the data bus 16. Digital data from the transmit buffer is provided via serial I/O device 40 to a transmitter 30. The transmitter is selectively operable to transmit in either a higher-speed, half-duplex mode or in a lower-speed, full-duplex mode. Selection of the particular mode of operation is under the direction of the processor. The transmitter output is coupled to the ring and tip conductors of the telephone line by a hybrid circuit 32. Coupled to the hybrid circuit 32 is a receiver 36. The receiver is capable of receiving at various data rates and in various modes. Selection of one of the receiver outputs is made by a multiplexer 38. The serial interface circuit 40 under the direction of the processor provides received data for passage through the RS-232 interface to the data terminal.

Although the operation of an implementation of the structure generally diagrammed in FIG. 1 will be presented, a summary overview of the operation of the diagrammed modem should be mentioned to aid in understanding the description which follows. In operation, the transmit buffer holds data from the data terminal. The transmitter receives data from the transmit data buffer and places a transmit data signal on the telephone line. The transmitter is selectively operable in either a lower-speed, full-duplex mode or a higher-speed, half-duplex mode in response to a mode control command from the processor. The processor monitors the amount of data being held in the transmit data buffer and produces the mode control command to the transmitter to establish the mode of transmitter operation based upon the amount of data in the transmit data buffer. If the data transmission demands of the data terminal are such that the transmit data buffer does not fill rapidly enough to require the higher-speed operation, the processor selects the lower-speed, full-duplex mode of transmission. However, with such operations as file transfers or full-screen applications when data is required to be rapidly transmitted, the lower-speed mode cannot prevent the buffer from rapidly filling. When the processor determines that a predetermined number of characters is reached in the transmit data buffer, it directs the transmitter to enter the higher-speed mode of operation. When the data transmission demands decrease, the processor so determines and can direct the transmitter to enter the lower-speed mode. Also, during the connect sequence between an originating modem and an answering modem, the initial exchange of link parameters and

other required control frame exchanges proceeds with the transmitter being directed to operate in the lower-speed, full-duplex mode. When the modems have been linked and data communication ensues, the processor directs the transmitter to operate in the higher-speed, half-duplex mode.

Referring next to FIG. 2, there is presented a functional diagram of the telephone line interface and power supply circuits. The power supply (not shown) is conventional and provides voltage levels of +12, +5, -12, and ground. The power supply output is applied to power supply filtering circuits to obtain the voltages for operating the various circuit elements. The hybrid circuit 32 is shown to receive the analog signal to be placed on the telephone line. This signal is provided over conductor 33. The analog signal is applied to an isolation line transformer 52 having protective diodes 53 and filter capacitor 54 connected across its terminals. The transformer is coupled to the tip and ring conductors of the telephone line connector by a hook control relay 56. Also connected to the tip and ring conductors is ring detect circuit 58.

An incoming signal is routed through the line transformer and hybrid circuit to separate signal paths 60, 61, and 62. Signal path 60 includes a gain stage 63 and equalizer circuit 64. Signal path 61 includes gain stage 65. Signal path 62 includes bandpass filter 66 and envelope detector 67. The outputs of the signal paths are variously applied to the circuitry shown in FIGS. 3 and 4.

With reference now to FIGS. 3 and 4, there is presented a more detailed functional diagram of the modem which is generally diagrammed in FIG. 1. The embodiment being described utilizes a microprocessor as the control circuit. Accordingly, there is provided a data bus 70, an address bus 72, and the control bus 74. The CPU 80 is coupled to the data bus by data bus buffer 82 and coupled to the address bus by address buffer 84. Coupled to the data bus are input latches 86, 88, and 90. Latch 86 accepts and holds signals from the data terminal interface. Latch 88 holds various internal modem signals. Latch 90 holds various inputs from the front panel switches. The latch enable signals are provided from decoding circuits 92 which is coupled to the control bus 74 and address bus 72.

The program for execution by the processor is contained in program ROM 94. This ROM is addressed by addresses output from the CPU over the address bus 72, and the ROM contents are provided to the CPU over data bus 70. The selection of the ROM is also under the direction of the CPU through decoding circuits 92.

Digital data from a data terminal for communication is placed in the transmit data buffer which includes random access memories 96 and 98. Additional random access memory storage is provided by random access memory 100. This memory is a nonvolatile memory that stores information such as telephone numbers and other information which is historical. A battery circuit 102 maintains the contents of RAM 100 during the time power is off. Also, during the time of resetting the processor, battery circuits 102 disables RAM 100.

Turning now to FIG. 4, the higher-speed transmit and receive functions are performed by a combined transmitter/receiver device 104. This device is suitably an R96FAX system available from the Semiconductor Products Division of Rockwell International Corporation. Device 104 is coupled to the data and address busses in order to receive directions as to the configuration for the operation desired. Serial digital data for serving as the modulating signal is provided to device 104 on the TXD line 105. The serial digital data is routed through a multiplexer 106. Referring again to FIG. 3, the TXD signal is obtained from serial input/output device 110 through switch 112. Device 110 is coupled to the data bus and receives frames of data from the data buffer random access memories 96 and 98 under the direction of the CPU. Digital data from the data terminal is provided through the RS-232 interface and applied serially to device 110 for conversion to parallel form. The CPU directs the parallel-form data from device 110 to data buffer random access memories 96 and 98. The CPU monitors the data frames being placed in the data buffer and keeps a running tabulation of the amount of data being placed in the data buffer. In a synchronous mode of operation of the transmitter, the TXD serial data stream from the RS-232 interface is passed around device 110 over line 114 and applied through switch 112 to multiplexer 106. It is only in the asynchronous mode of operation that the CPU directs data to be communicated through the serial input/output device 110.

Returning to FIG. 4, the transmitter further includes a lower-speed, full-duplex transmit and receive device 116. The serial data stream TXD is applied to the lower-speed transmitter/receiver device 116 from multiplexer 106 over signal path 118. Control of the lower-speed device 116 is provided by the CPU. Configuration and control instructions are placed in output latch 120 and provided to device 116.

The R96 FAX system implementing device 104 is a slow turnaround device. The use of the full-duplex device 116 provides fast carrier acquisition and link management. The fast carrier acquisition facility in combination with the high data throughput facility provides the desired high-speed data transmission over dial-up telephone lines and a full-duplex appearance at the data terminal interface.

As further shown in FIG. 4, the modem includes a dual tone multifrequency (DTMF) generator 122 which provides tones for dialing. Device 122 is controlled by the CPU with control commands placed in output latch 124. The analog transmit signal from the lower-speed transmitter 116 is applied to an amplifier 126. The output from tone generator 122 is also provided as an input to amplifier 126. The output of amplifier 126 and the analog transmit signal from higher-speed transmitter 104 are applied to a buffer amplifier 128. The output of amplifier 128 is the modem transmit signal applied over line 33 to hybrid circuit 32 in FIG. 2.

Further included in FIG. 3 is a set of drivers 130 providing signals to the RS-232 interface. Certain of the signals provided to the drivers are obtained through output latch 132 which is loaded through the data bus.

Another output latch 134 connected to the data bus provides controls for the front panel light-emitting diode displays 136.

Referring again to FIG. 2, the receive signal paths 60 and 61 provide the transmit signal from a remote modem to the lower-speed and higher-speed receiver portions, respectively. The signal RXA shown in FIG. 4 is being applied to device 104 which yields the receive signal on line 140. This signal is applied in FIG. 3 to multiplexer 142. When selected by multiplexer 142, the signal on line 40 is applied to the serial input/output device 110. The CPU may obtain received data from device 110 or direct passage of the serial data onto switch 144. The output from switch 144 is applied through driver 146 to the RS-232 interface as the receive signal RXD.

Referring again to FIG. 4, the receive signal from signal path 60 in FIG. 2 is applied to the lower-speed device 116. The receive signal from device 116 is provided over line 148 to multiplexer 150 in FIG. 3. The output of multiplexer 150 is applied to the input of the serial input/output device 110. The CPU acquires the receive signal data to descramble it and provide it back through device 110 to line 143 to become the RXD output to the data terminal interface.

A counter timing circuit 160 is controlled by the CPU. Device 160 includes timers which can be turned on or off by the CPU. Device 160 generates the various baud rate timing signals for the serial input/output communication device 110 from the T0 output over line 161. Another timer in device 160 provides a signal from output T1 over line 162 to multiplexer 164. When line 162 is selected by the multiplexer to be applied to device 110, the signal is provided to device 110.

Referring to Fig. 5, there is presented a diagram illustrating the connect sequence for the modem of Figs. 1-4. The diagram illustrates the transmitted and received signals for both an originate modem and an answer modem. When the originating modem initiates a call, the remote central office sends a ring signal to the answer modem which is detected on the ring indicator RI line. The answer modem goes off-hook and transmits an answer tone of 2225 Hz. This tone is received by the originate modem and after 455 milliseconds, the originate modem begins sending a carrier modified by logic 0 data, referred to as scrambled zeros for 100 milliseconds followed by scrambled ones. After approximately 50 to 100 milliseconds of scrambled zeros being received, the answer modem identifies that the originating modem is compatible and transmits scrambled zeros back to the originate modem. The originate modem then identifies that the answer modem is compatible.

The modems then exchange link parameters for error control. The originate modem first sends approximately 23 bytes of link parameter information. The answer modem receives the link parameters and if any parameters need to be changed, it sends update link parameters to the originate modem. After the update link parameters are exchanged, the CXR and CTS lines are turned on at both modems.

When enough data accumulates in the transmit data buffer at either end to go high speed, the modems exchange control frames. Both modems then go into a squelch for a period of time, and the transmitter of the corresponding modem begins sending data at 9600 bps. At the end of data transmission, the modems squelch and 1200 bps, full-duplex transmission is resumed and acknowledgments sent for frames received. The speed is maintained until it is time for either modem to transmit data to the other modem at higher speed. At that time, both modems squelch, and thereafter the operation continues as described above. Data transmission proceeds as required by the data transmission demands of the data terminals for the modems.

Referring next to Fig. 6 there is a flowchart of the data transmission routine followed by the modem operating as an originate modem. At the start of operation, the modem performs the originate/answer connect sequence by calling and establishing a link with the answer modem in a lower-speed, full-duplex mode. There follows an exchange of link parameters with the remote answer modem and confirmation of agreement on the parameters. The modem then enables the sending and receiving of data to the data terminal equipment. If the link parameters do not agree, the modem disconnects.

When the sending and receiving of data begins, a check is made for data from the data terminal. If data is being received from the data terminal, it is compressed and put into the transmit data buffer. A check is made to see whether there is enough data to go higher-speed, half-duplex. If so, the modem sets up the higher-speed, half-duplex link and data is transmitted in that mode. If there is not enough data to go higher-speed, data is transmitted at lower-speed in the full-duplex mode.

At the the end of data transmission in the higher-speed mode, the originate modem asks the remote modem to go lower-speed, full-duplex and to send an acknowledgement. The modems establish the lower-speed, full-duplex link. The modem then checks for acknowledgment from the remote modem. If the acknowledgement does not come within a prescribed time out period, the modem initiates a recovery to establish the lower-speed link. If the acknowledgment is received, the modem determines whether the remote modem has requested higher-speed operation. If so, the originate modem acknowledges the request for higher-speed and establishes the half-duplex link and sets up in a receive mode. There continues to be monitoring for a request to go lower-speed. When the request is received, the modem establishes the lower-speed, full-duplex link and sends an acknowledgement that all data frames have been received. The received data frames are decompressed and sent to the data terminal. The originate modem then returns to check for any data from the data terminal. The diagrammed sequence continues until completion of the required data communication task.

FIG. 7 flowcharts an operational sequence of the modem involving data communication that automatically changes between speeds of transmission based upon data transmission demand during a communication and upon the quality of the data transmissions. When the modem begins transmitting, it checks for data from the data terminal. The data for transmission is compressed and stored in the transmit data buffer. Next, there is evaluation of whether any data is waiting for retransmission. If so and there is enough to go higher-speed, the modem sends control frame information to the remote modem to go higher-speed. The higher-speed, half-duplex link is set up and transmission of data begins. At the conclusion of data transmission, a control frame is sent requesting the remote modem to go into the lower-speed mode. The modem then awaits reception of an acknowledgement. If the acknowledgement does not come within a prescribed time out period, the modem initiates recovery by establishing the link and reentering the transmit sequence. If the request to go lower-speed is acknowledged, the routine goes back to the beginning of the transmit sequence.

If there is no acknowledgement that all data frames were received properly, there is consideration of whether a predetermined number of data frames have been transmitted at higher-speed (e.g. 25 frames). If so, there is a check to determine whether the transmitted data frames included any retransmissions. If there was retransmission of any data frame for a predetermined number of times (e.g. 8 times), there is a calculation of the retransmit frame ratio. Based upon the calculated ratio, a determination is made whether the quality of the data transmission indicates qualification for a fallback in speed. If there had been retransmission of any data frame at least the predetermined number of times, and if the modem is linked in the lowest fallback speed, then the modem disconnects. If the link is not in the lowest fallback speed, the modem sets up the link for one step lower in speed and reenters the transmit sequence.

If the evaluation to determine whether a predetermined number of preceding transmitted frames included any retransmitted data indicates that none were retransmitted frames, the routine makes an evaluation for qualification to fallforward to a higher speed. If the qualification is not met, the transmit sequence is reentered at the same speed. But if the data transmission quality qualifies for a fallforward in speed, and the link is not already in the highest speed, the modem sets up the link for a one step higher speed of transmission.

The routine in Fig. 7 illustrates the ability of the modem to adapt its speed to the quality of the telephone line. As indicated, the modem can either fallback to a lower speed or fallforward to a higher speed. In general, to determine the quality of the line, the processor of the modem constantly monitors the number of errors in data transmission as reflected by the number of retransmitted data frames. If the number of retransmissions is high, indicating too many errors are encountered and line quality is poor, the modem drops down to the next lower speed until an acceptable reduction in errors in transmission is achieved. If the line quality improves and the number of errors is reduced, the modem will automatically fallforward to the next higher speed.

The foregoing description of the present invention has been directed to particularly preferred embodiments for purposes of explanation and illustration. It will be apparent, however, to those skilled in this art that modifications and changes may be made in the apparatus and operation described without departing from the scope of the invention.

Claims

1. Apparatus for communication of data over a telephone line, characterized by:

a transmit data buffer for accepting digital data;

a transmitter receiving data from the transmit data buffer, for placing a transmit signal on a telephone line;

said transmitter being selectively operable in either a lower-speed, full-duplex mode or a higher-speed, half-duplex mode in response to a mode control command; and

a control circuit for monitoring the amount of data being placed in the transmit data buffer and producing the mode control command to the transmitter to establish the mode of transmitter operation based upon the data transmission demand.

2. Apparatus for communication of data over a telephone line to a remote data receiver, characterized by:

a transmit data buffer for holding data;

a transmitter receiving data from the transmit data buffer, for placing a transmit signal on a telephone line to communicate data and control frames;

said transmitter being selectively operable in either a lower-speed, full-duplex mode or a higher-speed, half-duplex mode in response to a control command; and

a control circuit coupled to the transmitter, for providing a control frame to be sent by the transmitter to the remote data receiver to signal higher-speed operation and producing the control command to the transmitter to select the higher-speed, half-duplex mode based upon the amount of data in the transmit data buffer.

3. The mode of claim 2 characterized in that said control circuit further provides a control frame to be sent by the transmitter to the remote data receiver to signal lower-speed operation and producing the control command to the transmitter to select the lower-speed, full-duplex mode.

4. Apparatus for communication of data over a telephone line between a local data terminal and a remote modem, characterized by:

a transmitter for accepting data and control frame information and placing a transmit signal on a telephone line;

said transmitter being selectively operable in either a lower-speed, full-duplex mode or a higher-speed, half-duplex mode in response to a control command;

a receiver for accepting a transmit signal of link control frame from a remote modem over the telephone line and providing a receive signal of control frame information;

a transmit data buffer for accepting data from a local data terminal;

a control circuit coupled to the transmitter to provide control frame information and the mode control command, and coupled to the receiver to obtain the receive signal of control frame information; and

the control circuit for providing the mode control command to the transmitter to select the lower-speed, full-duplex mode during an exchange of control frame information with a remote modem, and for thereafter monitoring the transmit data buffer and providing a mode control command to the transmitter to select the higher-speed, half-duplex mode based upon the data transmission demand.

5. A modem for providing communication of data over a telephone line between a local data terminal and a remote modem, characterized by:

a transmitter for accepting data and control frame information and placing a transmit signal on a telephone line to the remote modem;

said transmitter being selectively operable in either a lower-speed, full-duplex mode or a higher-speed, half-duplex mode in response to a control command;

a receiver for accepting a transmit signal from a remote data communication unit over the telephone line in either a higher-speed, half-duplex mode or a lower-speed, full-duplex mode in response to a mode control command and providing a receive signal;

a transmit data buffer for accepting data from a local data terminal;

a processor coupled to the transmitter and the receiver and providing mode control commands thereto;

the processor controlling transmitter and receiver operation during a connect sequence with a remote modem to effect an exchange of control frame information therebetween and thereafter controlling transmitter and receiver operation to effect data communication with the remote modem based upon the data transmission demands by monitoring the data going to the transmit data buffer and providing a mode control command to the transmitter to select the higher-speed, half-duplex mode upon determining a predetermined number of characters in the buffer for communication and providing a mode control command to the transmitter to select the lower-speed, full-duplex mode upon determining that insufficient data is in the buffer to require higher-speed operation.

6. The modem of claim 5 characterized in that the processor further monitors the receive signal to determine a request by the remote modem for higher-speed operation and provides a control command to the receiver to accept the remote modem transmit signal in a higher-speed, half-duplex mode.

7. The modem of claim 5 characterized in that the processor further monitors the receive signal to determine a request by the remote modem for lower-speed operation and provides a control command to the receiver to accept the remote modem transmit signal in a lower-speed, fullduplex mode.

8. Apparatus for providing communication of data over a telephone line, characterized by:

a transmitter receiving frames of data, for placing a transmit signal on a telephone line;

said transmitter being selectively operable to transmit data at discrete data rates in response to a speed control command;

a processor for monitoring the transmission of data frames to determine data transmission errors, and for producing the speed control command to select the data rate of the transmitter; and said processor causing the data transmission rate to fallback to a lower data rate or to fallforward to a higher data rate based upon the determination of data transmission errors.

9. The apparatus of claim 8, characterized in that the processor determines data transmission errors based upon the retransmissions of data frames.

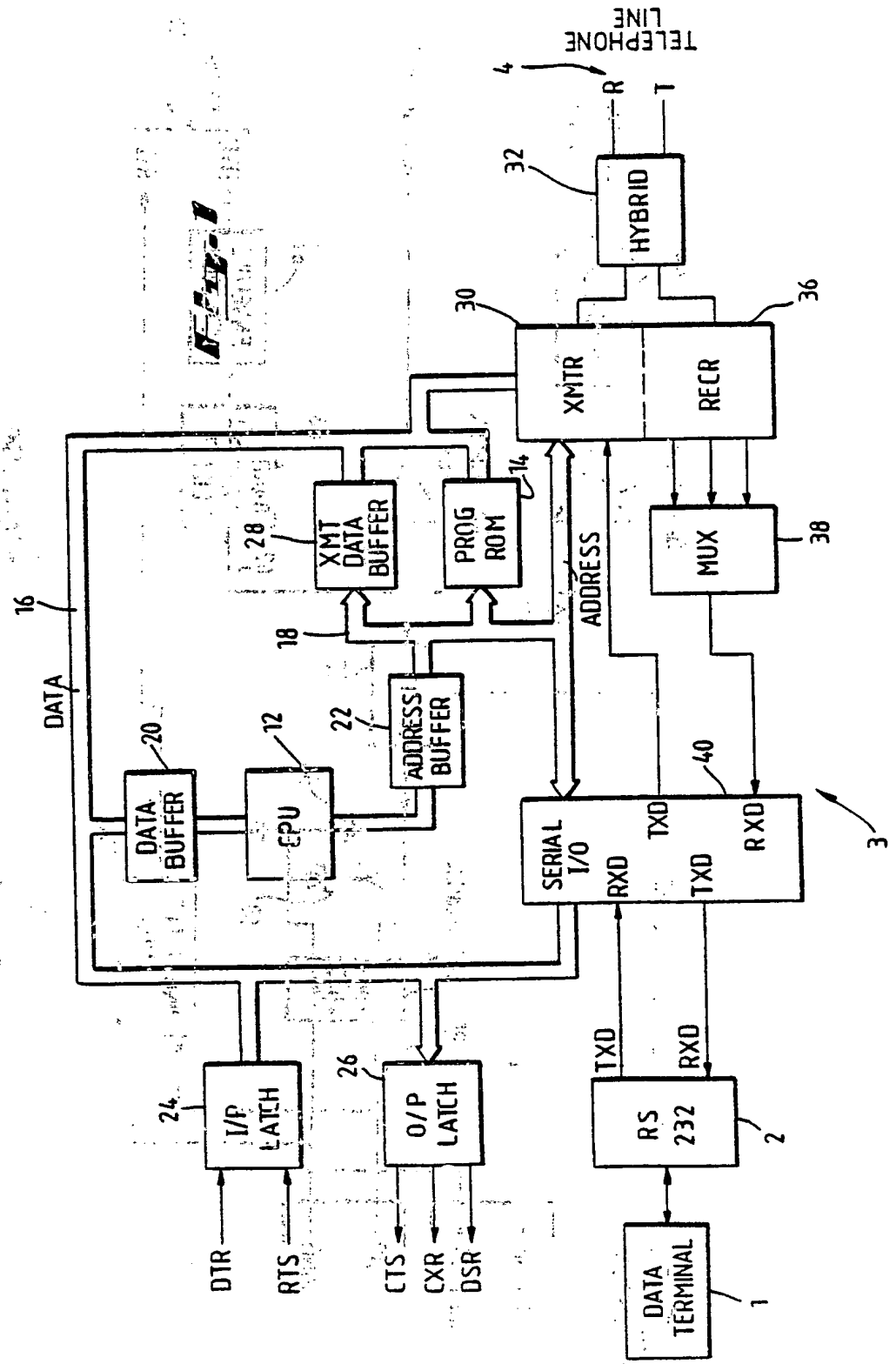
10. Apparatus for communication of data over a telephone line, characterized by:

a receiver for accepting a transmit signal of data or control frame information over the telephone line and providing a receive signal;

said receiver being selectively operable to accept a transmit signal in either a higher-speed, half-duplex mode or a lower-speed, full-duplex mode in response to a mode control command; and

a control circuit coupled to the receiver to obtain the receive signal of control frame information, said control circuit for providing the mode control command to the receiver to select the lower-speed, full-duplex mode or the higher-speed, half-duplex mode based upon a receive signal of control frame information.

11. The apparatus of claim 10 further characterized by: a transmitter for placing a transmit signal on a telephone line.


TELEPHONE LINE
4
R
T
32
HYBRID
30
XMTR
36
RECR
XMT DATA BUFFER
28
PROG ROM
14
ADDRESS
MUX
38
16
18
DATA
22
ADDRESS BUFFER
20
DATA BUFFER
12
CPU
SERIAL I/O
RXD
TXD
TXD
RXD
40
3
24
I/P LATCH
26
O/P LATCH
TXD
RXD
RS 232
2
DTR
RTS
CTS
CXR
DSR
DATA TERMINAL
1

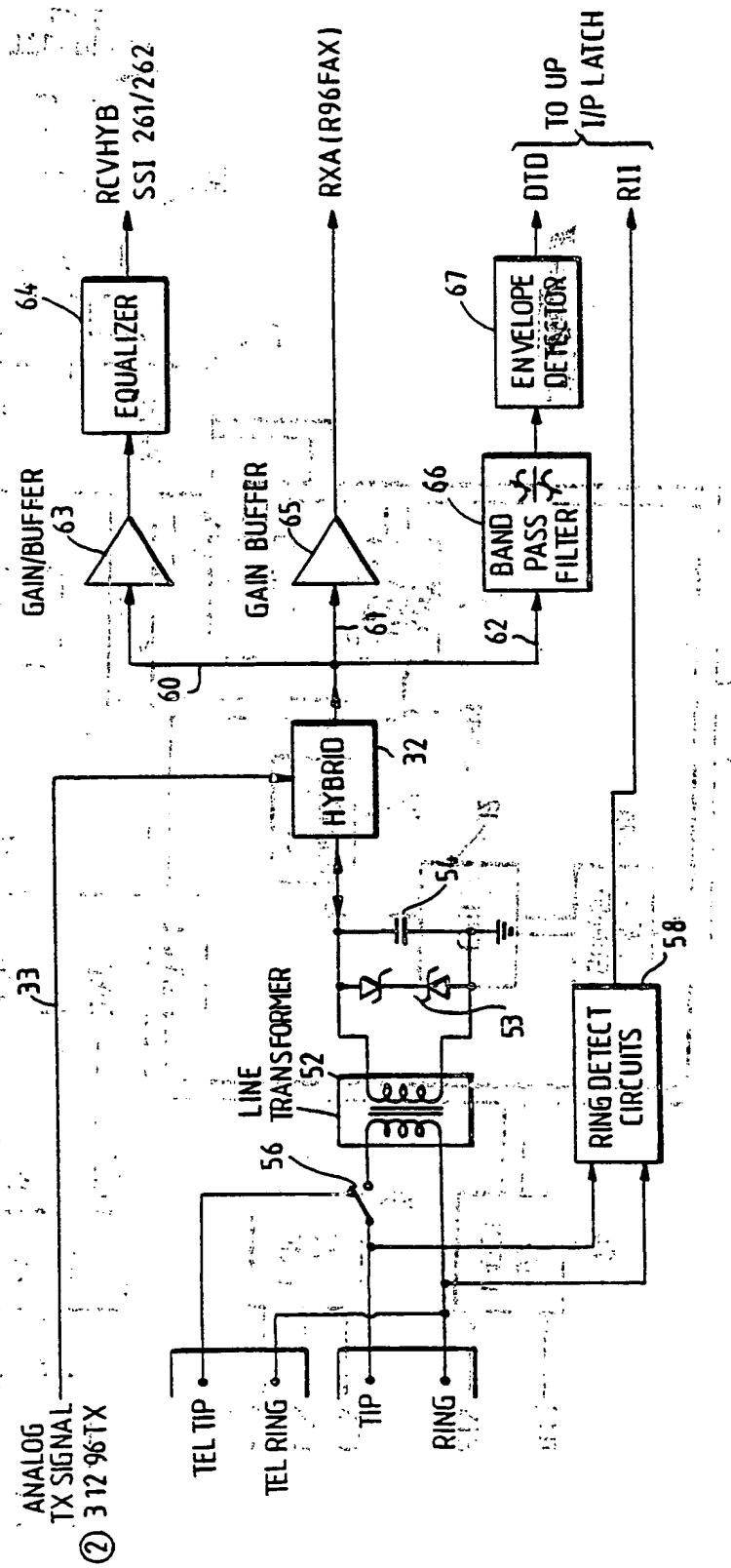

ANALOG TX SIGNAL
② 3 12 96 TX
33
TEL TIP
TEL RING
TIP
RING
LINE TRANSFORMER
52
56
53
54
15
HYBRID
32
60
GAIN/BUFFER
63
EQUALIZER
64
RCVHYB
SSI 261/262
GAIN BUFFER
65
61
RXA (R96FAX)
62
BAND PASS FILTER
66
ENVELOPE DETECTOR
67
DTD
TO UP I/P LATCH
RII
RING DETECT CIRCUITS
58
50
POWER SUPPLY FILTERS
+12V
+5V
-12V
-5V
GND
POWER SUPPLY
+12V
+5V
-12V
GND

Fig-2

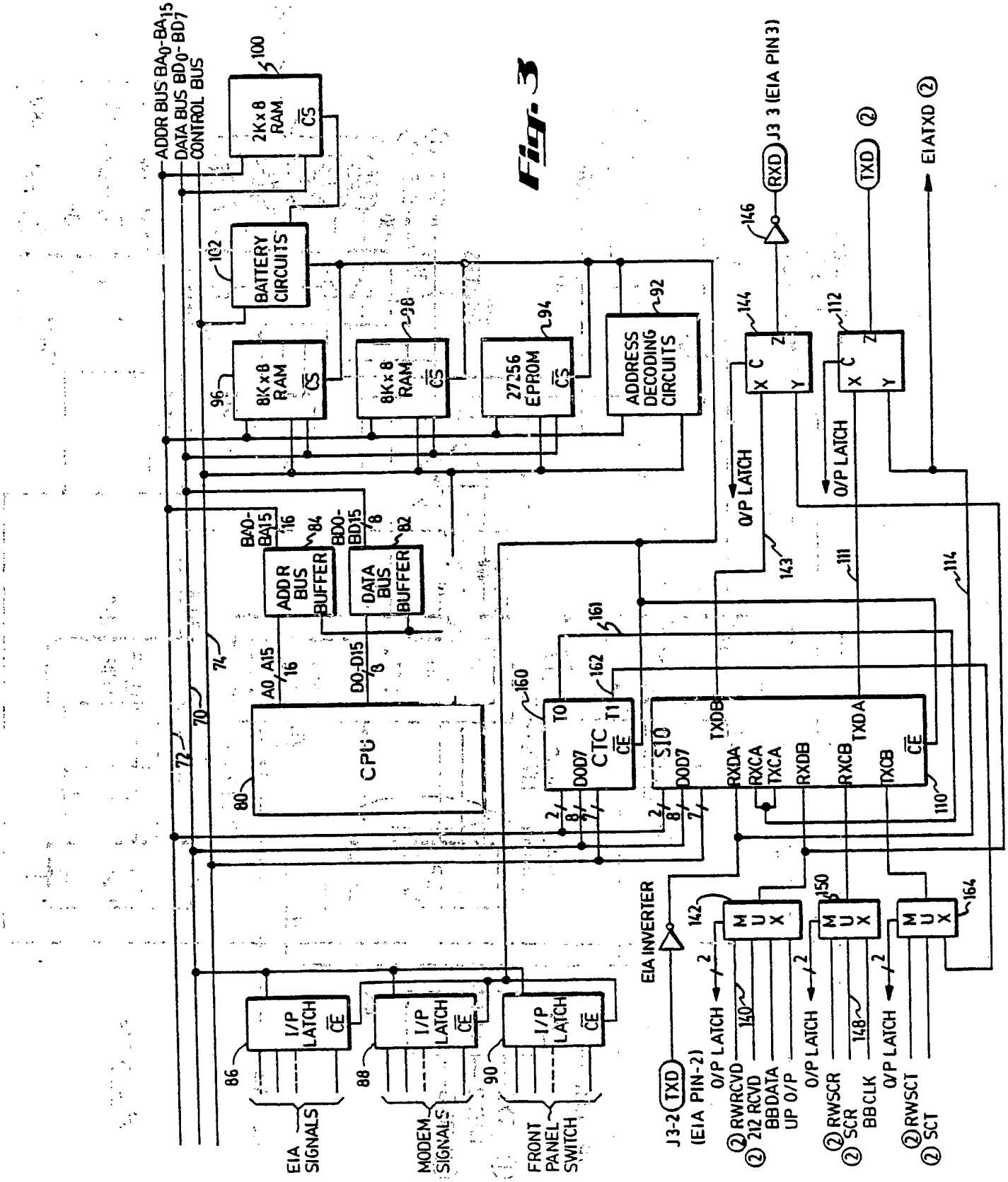

ADDR BUS BA0-BA15
DATA BUS BD0-BD7
CONTROL BUS
2K x 8 RAM
100
BATTERY CIRCUITS
102
8K x 8 RAM
96
8K x 8 RAM
98
27256 EPROM
94
ADDRESS DECODING CIRCUITS
92
BA0-BA15
16
84
BD0-BD15
8
82
ADDR BUS BUFFER
DATA BUS BUFFER
A0 A15
16
D0-D15
8
74
70
72
80
CPU
160
161
162
TO
T1
CTC
CE
D0D7
S10
TXDB
RXDA
RXCA
TXCA
RXDB
RXCB
TXDA
TXCB
110
111
112
114
143
144
146
O/P LATCH
RXD
J3 3 (EIA PIN 3)
TXD
EIATXD
EIA INVERTER
142
MUX
150
164
I/P LATCH
86
88
90
EIA SIGNALS
MODEM SIGNALS
FRONT PANEL SWITCH
J3-2 (EIA PIN-2)
TXD
O/P LATCH
140
RWRCVD
212 RCVD
BBDATA
UP O/P
148
RWSCR
SCR
BBCLK
RWSCT
SCT

Fig. 3

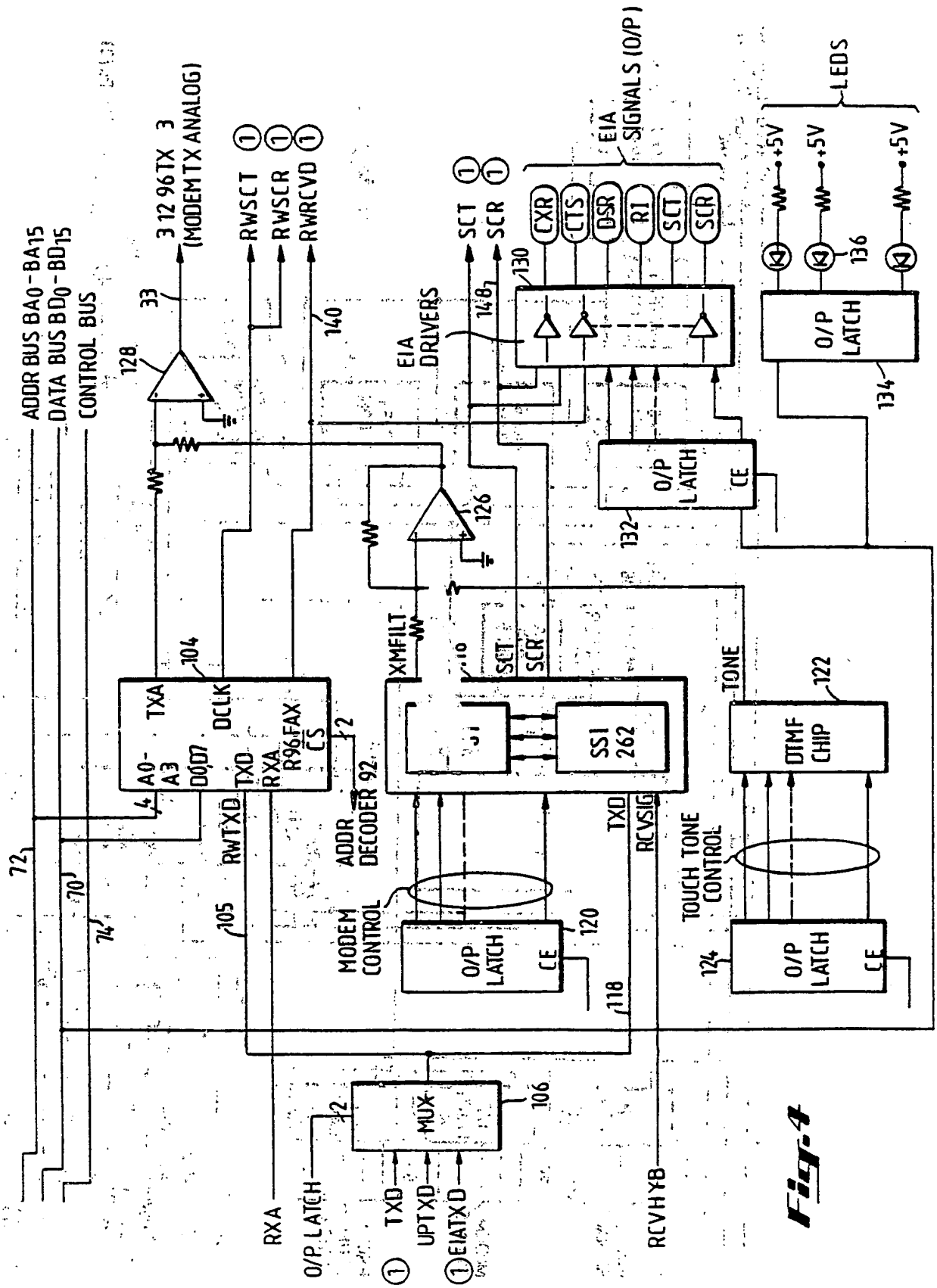

ADDR BUS BA0-BA15
DATA BUS BD0-BD15
CONTROL BUS
72
70
74
3 12 96TX 3
(MODEM TX ANALOG)
33
128
RWSCT
RWSCR
RWRCVD
140
EIA DRIVERS
SCT
SCR
148
EIA SIGNALS (O/P)
CXR
CTS
DSR
RI
SCT
SCR
130
+5V
LEDS
136
O/P LATCH
134
126
132
CE
104
TXA
A0-A3
DCLK
D0/D7
TXD
RXA
R96FAX CS
RWTXD
105
XMFILT
110
SCT
SCR
SS1 262
ADDR DECODER 92
MODEM CONTROL
O/P LATCH
CE
120
118
TXD
RCVSIG
TONE
122
DTMF CHIP
TOUCH TONE CONTROL
124
MUX
106
RXA
O/P LATCH
TXD
UPTXD
EIATXD
RCVHYB

Fig-4

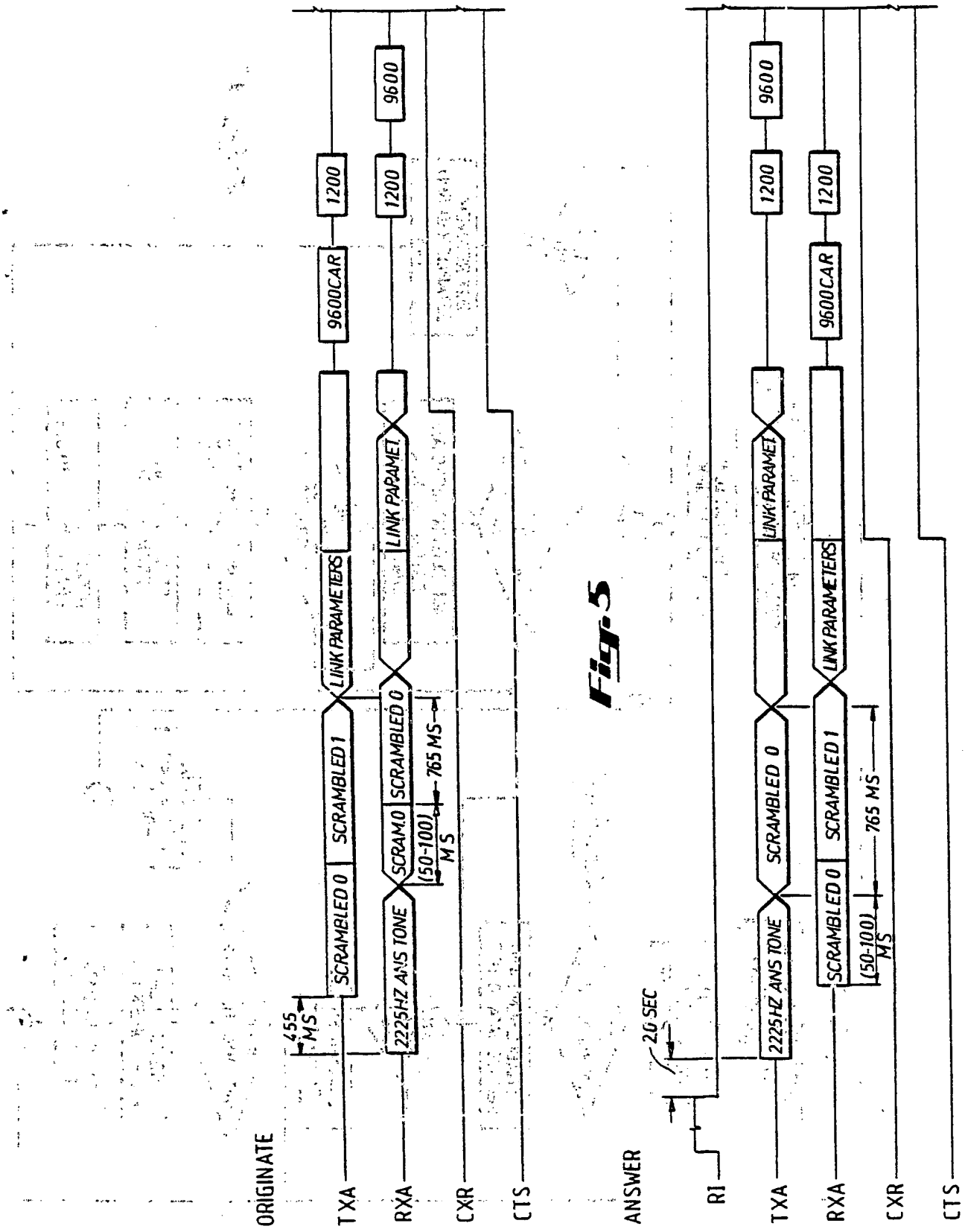

ORIGINATE
TXA
RXA
CXR
CTS
455 MS
SCRAMBLED 0
SCRAMBLED 1
2225HZ ANS TONE
SCRAM.0
SCRAMBLED 0
(50-100) MS
765 MS
LINK PARAMETERS
LINK PARAMET
9600CAR
1200
1200
9600
ANSWER
RI
TXA
RXA
CXR
CTS
2.6 SEC
2225HZ ANS TONE
SCRAMBLED 0
SCRAMBLED 1
(50-100) MS
765 MS
LINK PARAMET
LINK PARAMETERS
9600CAR
1200
1200
9600

Fig. 5

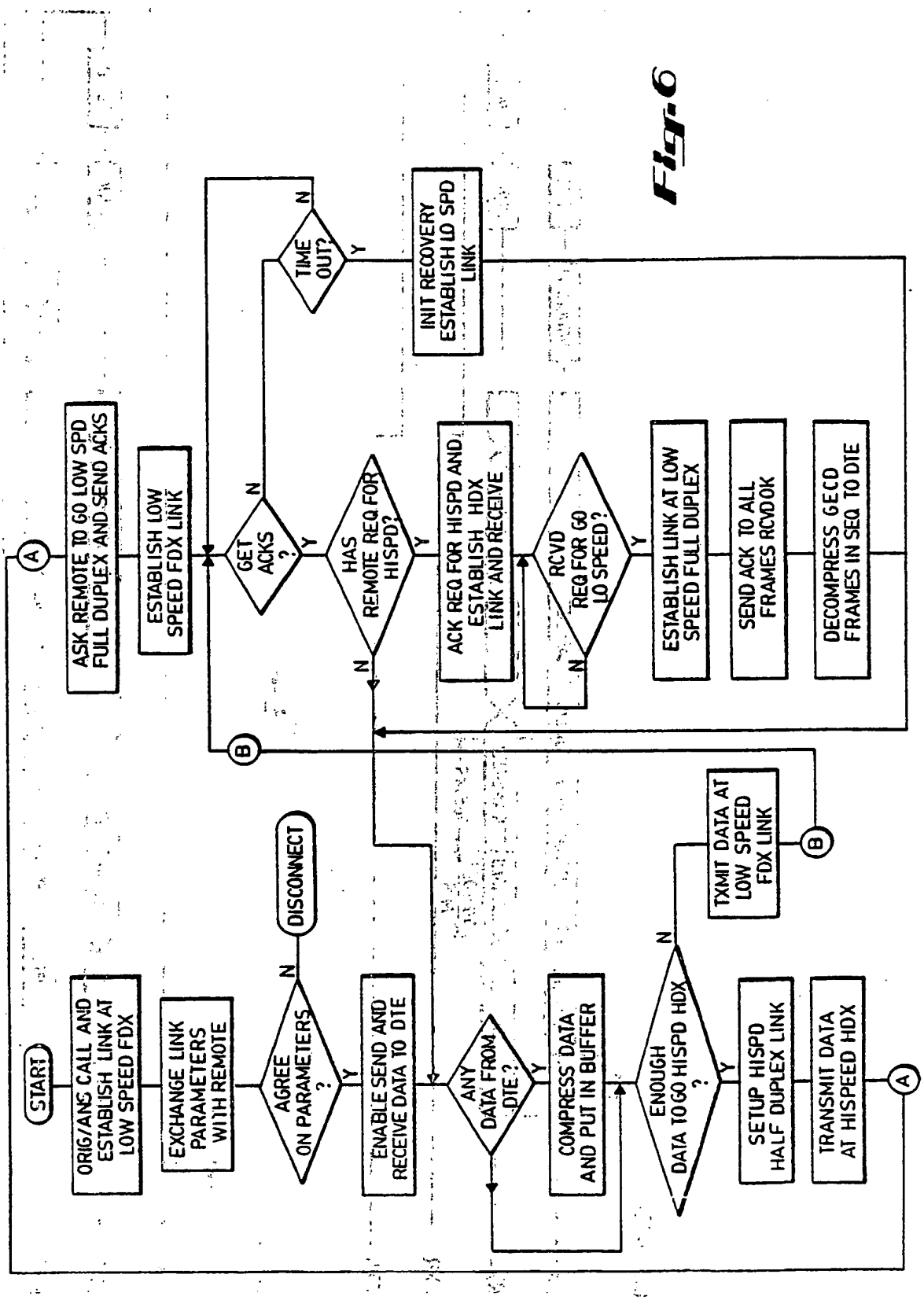

START
ORIG/ANS CALL AND ESTABLISH LINK AT LOW SPEED FDX
EXCHANGE LINK PARAMETERS WITH REMOTE
AGREE ON PARAMETERS ?
N
DISCONNECT
Y
ENABLE SEND AND RECEIVE DATA TO DTE
ANY DATA FROM DTE ?
Y
COMPRESS DATA AND PUT IN BUFFER
ENOUGH DATA TO GO HISPD HDX ?
N
TXMIT DATA AT LOW SPEED FDX LINK
B
Y
SETUP HISPD HALF DUPLEX LINK
TRANSMIT DATA AT HISPEED HDX
A
A
ASK REMOTE TO GO LOW SPD FULL DUPLEX AND SEND ACKS
ESTABLISH LOW SPEED FDX LINK
GET ACKS ?
N
TIME OUT?
N
Y
INIT RECOVERY ESTABLISH LO SPD LINK
Y
HAS REMOTE REQ FOR HISPD?
N
Y
ACK REQ FOR HISPD AND ESTABLISH HDX LINK AND RECEIVE
RCVD REQ FOR GO LO SPEED?
N
Y
ESTABLISH LINK AT LOW SPEED FULL DUPLEX
SEND ACK TO ALL FRAMES RCVDOK
DECOMPRESS &ECD FRAMES IN SEQ TO DTE
B

Fig.6

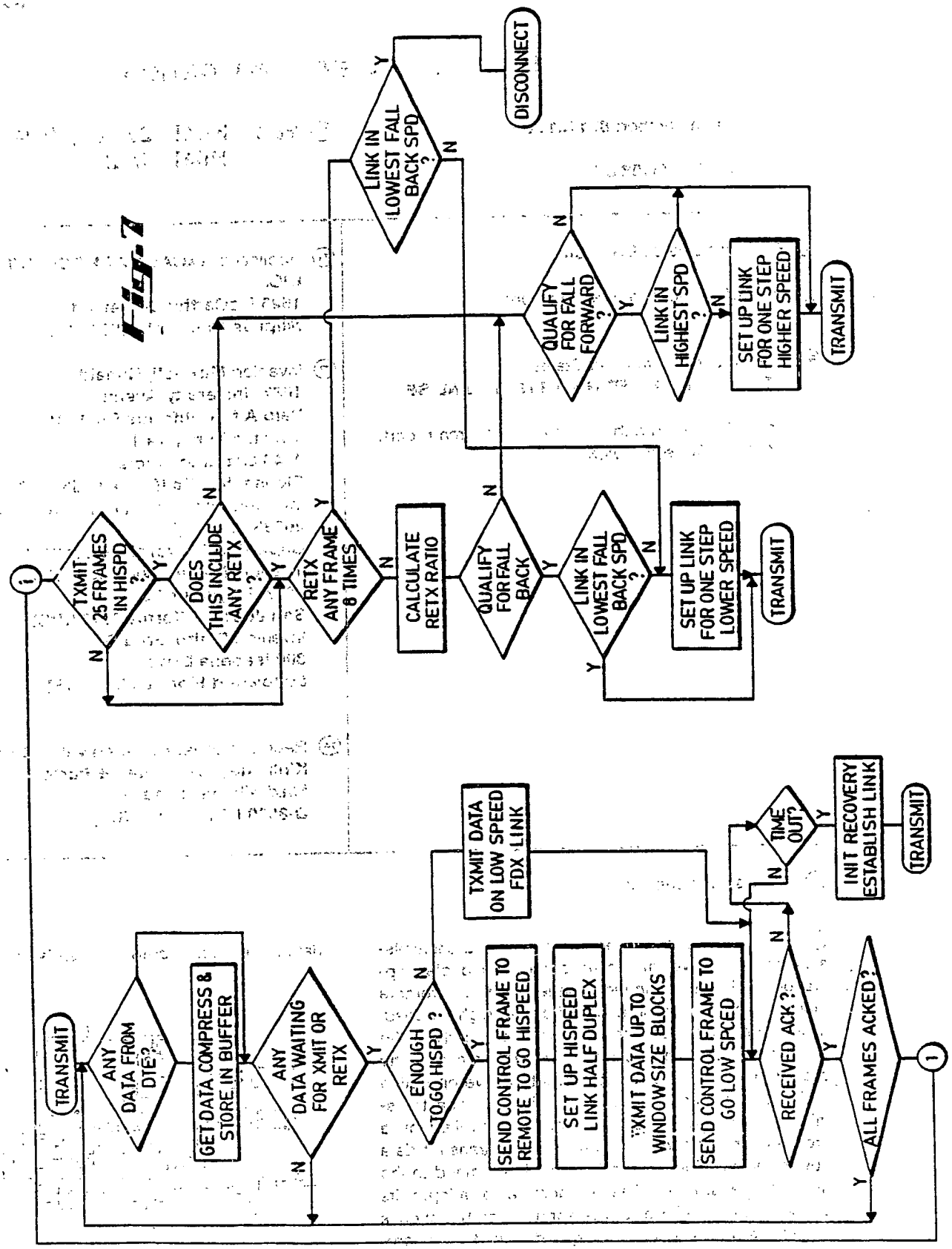

TRANSMIT
ANY DATA FROM DTE?
GET DATA COMPRESS & STORE IN BUFFER
ANY DATA WAITING FOR XMIT OR RETX
ENOUGH TO GO HISPD ?
TXMIT DATA ON LOW SPEED FDX LINK
SEND CONTROL FRAME TO REMOTE TO GO HISPEED
SET UP HISPEED LINK HALF DUPLEX
XMIT DATA UP TO WINDOW SIZE BLOCKS
SEND CONTROL FRAME TO GO LOW SPCED
RECEIVED ACK ?
TIME OUT?
INIT RECOVERY ESTABLISH LINK
TRANSMIT
ALL FRAMES ACKED?
1
TXMIT 25 FRAMES IN HISPD ?
DOES THIS INCLUDE ANY RETX ?
RETX ANY FRAME 8 TIMES
CALCULATE RETX RATIO
QUALIFY FOR FALL BACK
LINK IN LOWEST FALL BACK SPD ?
SET UP LINK FOR ONE STEP LOWER SPEED
TRANSMIT
LINK IN LOWEST FALL BACK SPD ?
DISCONNECT
QUALIFY FOR FALL FORWARD ?
LINK IN HIGHEST SPD ?
SET UP LINK FOR ONE STEP HIGHER SPEED
TRANSMIT

Fig. 7

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Office européen des brevets

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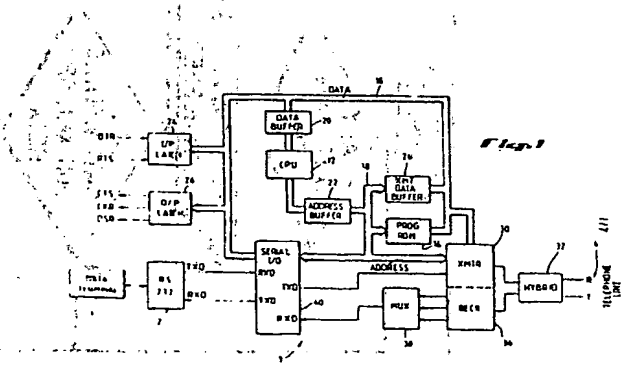
(54) High speed modem.

(57) A modem is disclosed having a data transmission protocol involving lower-speed, full-duplex operation during the connect sequence with a remote modem and an automatic switch to higher-speed, half-duplex operation for data transfer. Further, the modem data transmission involves transparently-changing between lower-speed, interactive operation and higher-speed operation based upon data transmission demands. The operation is controlled by a processor monitoring the contents of a transmit data buffer and providing a mode control command to the modem transmitter. The modem also adapts its speed to the quality of the telephone line by fallback or fallforward to a different speed based upon predetermined data frame retransmission criteria.



EP 0 260 470 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 87 11 2112

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
A	DE-A-3 515 836 (RICOH) * Abstract; claim 1; page 6, lines 5-14 *	1,8	H 04 L 27/00 H 04 L 5/16 H 04 L 1/12
A	IBM TECHNICAL DISCLOSURE BULLETIN, vol. 17, no. 11, April 1975, pages 3301-3302, New York, US; J.C.ABBIATE et al.: "Variable-data transmission modem" * Page 3301, lines 1-2; page 3302, lines 8-10 *	1,8	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

H 04 L

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20-10-1989	VEAUX, C.J.

CATEGORY OF CITED DOCUMENTS

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